Effect of Different Levels and Timing of Zinc Foliar Application on Growth, Yield and Quality of Sunflower Genotypes (*Helianthus annuus* L., *Compositae*)

Dr. Saad A. M. Al-Doori
Department of Science
College of Basic Education / University of Mosul

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Abstract:

Because of the calcareous nature of soils in Mosul city and the high value of the soil pH, most micro nutrients have negligible availability in these soils, therefore an field experiment was conducted during two successive growing seasons 2009-2010 and 2010-2011 to determinate the response of growth, yield and quality of sunflower *(Helianthus annuus* L.*)* genotypes to different levels and timing of zinc foliar application. The experiment comprised of three levels of zinc sprayed on the plant leaves one dose (0, 7.5 and 15 $mg.l^{-1}$), three sunflower genotypes (Manon, Fodak and Sunbred) and three timing of zinc application (heading stage, flowering stage and seed filling stage). It was conducted according to Randomized Completely Block Design with split - split plot with three replications. The results could be summarized as: The addition of zinc sprayed on the plant leaves with concentration 7.5 $mg.l^{-1}$ led to an significant increase in characteristics: plant height, leaf area, number of $seeds.head^{-1}$, weight of thousand seed, seed yield per plant, total seed yield, seed oil content, seed protein content and oil yield, protein yield, while increasing concentration of zinc to 15 $mg.l^{-1}$cause a significant decrease in all investigated characteristics in the two growing seasons. Fodak genotype gave a high mean for characters: plant height, stem diameter, leaf area, number of $seeds.head^{-1}$, seed yield per plant, total seed yield, seed oil content, seed protein content, oil yield and protein yield in both seasons 2009-2010 and 2010-2011. Delaying timing of zinc foliar application to flowering stage causes an significant increase of all investigated characteristics in both seasons 2009-2010 and 2010-2011.

تأثير رش الزنك بمستويات ومواعيد مختلفة في نمو تراكيب وراثية من زهرة الشمس وحاصلها ونوعيتها
(*Helianthus annuus* L., *Compositae*)

د.سعد احمد محمد احمد الدوري
قسم العلوم
كلية التربية الأساسية/ جامعة الموصل

ملخص البحث:

بسبب طبيعة الأرض الكلسية في مدينة الموصل وارتفاع قيمة الأس الهيدروجيني للتربة، فان معظم العناصر الغذائية الصغرى يكون توفرها نادراً في تلك الترب، لذلك نفذت تجربة حقلية خلال موسمي النمو المتعاقبين 2009–2010 و2010–2011 لتحديد استجابة نمو تراكيب وراثية من زهرة الشمس وحاصلها ونوعيتها (*Helianthus annuus* L.) للرش الورقي بالزنك بمستويات ومواعيد مختلفة. تألفت التجربة من ثلاثة مستويات لرش الزنك على أوراق النبات دفعة واحدة (0، 7.5 و15 ملغم.لتر$^{-1}$) وثلاثة تراكيب وراثية من زهرة الشمس (مانون، فوداك وسنبرد) وثلاثة مواعيد لرش الزنك (خلال طور تكوين القرص الزهري، طور التزهير وطور امتلاء البذرة). نفذت التجربة وفق نظام القطع المنشقة–المنشقة بتصميم القطاعات العشوائية الكاملة بثلاثة مكررات. وتم التوصل إلى النتائج الآتية: أدى إضافة الزنك رشا" على أوراق النبات بتركيز 7.5 ملغم.لتر$^{-1}$ إلى زيادة معنوية في صفات: ارتفاع النبات، المساحة الورقية، عدد البذور.قرص$^{-1}$، وزن الألف بذرة، حاصل البذور للنبات الفردي، حاصل البذور الكلي، نسبتي الزيت والبروتين وحاصلي الزيت والبروتين، بينما سبب زيادة تركيز الزنك المضاف بمعدل 15 ملغم.لتر$^{-1}$ إلى انخفاض معنوي في جميع الصفات المدروسة في كلا موسمي الدراسة. أعطى التركيب الوراثي فوداك أعلى متوسط للصفات: ارتفاع النبات، قطر الساق، المساحة الورقية، عدد البذور.قرص$^{-1}$، حاصل البذور للنبات الفردي، حاصل البذور الكلي، نسبتي الزيت والبروتين وحاصلي الزيت والبروتين في كلا الموسمين 2009–2010 و2010–2011. سبب تأخير موعد رش الزنك إلى طور التزهير زيادة معنوية في جميع الصفات المدروسة في كلا موسمي الدراسة 2009–2010 و2010–2011.

Introduction:

Sunflower (*Helianthus annuus* L.) is one of the most widely cultivated oil crops in the world. In recent years, the planted area has increased because its high oil yield. Many growers believe that sunflowers do not require as much applied fertilizer as cereals. Sunflowers have an extensive root system which may help in utilizing residual soil nutrients. Zinc is an micro nutrient element for plants that its deficiency is rarely observed in the soil. This element is used to increased other nutrients uptake. Increasing soil pH is considered, as an effective way to deal with the stabilization of nutrients in calcareous and alkaline soil. In calcareous and alkaline soil due to high pH and high concentration of calcium ions, some nutrients such as zinc, iron and phosphorus, that their availability are dependent on pH are established (Tisdale *et al*., 1993). Zn application at a rate of 5 $mg.l^{-1}$ gave the highest seed and oil yield per ha^{-1} (Al-Doori and Al-Dulaimy, 2012). The availability of zinc throughout the growing season is one environmental factor which varies considerably among commercial sunflower fields due to various fertilization rates, different soils and variation in rainfall. Previous research has indicated that under zinc limiting conditions, zinc fertilization tends to increase seed protein content at the expense of oil (Coleman, 1992; Gitte *et al.*, 2005; Mirzapour and Khoshgoftar, 2006; Martin *et al.*, 2007; Chhotu *et al.*, 2008 and Marie and Howarth, 2009). Timing of zinc application during the growing season influenced seed yield and oil yield. (Babaeian *et al.*, 2011), who applied zinc to the leaves during flowering stage, also found a increase in seed yield and oil yield with increasing levels of zinc application. The present investigation was planned to study the effects of both the amount and timing of zinc foliar application on the seed composition, seed yield, potential oil yield, potential protein yield and potential quality of the oil and protein to three sunflower genotypes.

Materials and methods:

The study included two field experiments of three sunflower genotypes conducted during 2009-2010 and 2010-2011 growing season at Sheikh Mohamed location to determinate effect of different levels and timing of zinc foliar application on growth, yield and quality. Sheikh Mohamed is located (25km) in the west north region of Mosul city at Nineveh province. Climatically, the region placed in the semiarid temperature zone cold winter and hot summer. Average rainfall is about 375 mm that most rainfall concentrated between winter and spring. Each experiment included eighty one treatments comprising the combinations of three genotypes (Manon, Fodak and Sunbred) with three levels of zinc (0, 7.5 and 15 $mg.l^{-1}$) sprayed on the leaves plants one dose during heading stage, flowering stage and seed filling stage as zinc sulphate ($ZnSo_4.7H_2O$, 35% Zn). The seeds were sown by putting three seeds to hills by hand in April 5th, 2nd and harvested in August 10th, 4th for 2009-2010 and 2010-2011 growing seasons, respectively. Super phosphate 120 $kg.hectar^{-1}$ (45% P_2O_5) and potassium (48%K_2O) were applied (60 kg. $hectar^{-1}$) to the soil during the sowing period. Nitrogen fertilizer was applied to the soil surface in two equal doses, half with sowing and the remaining half at immediately after one of month after sowing at a rate of 100 $kg.hectar^{-1}$ as form of urea (46%N). Each plot 24 M^2 (5*4.8) included six ridges 80 cm apart and five meters long and the distance between hills was 30 cm apart to attain a plant density of 41666 plants.hectar^{-1}. The first irrigation was applied immediately after sowing and after wards irrigation was scheduled at about four days intervals. Normal cultural practices, control of weeds of growing sunflower were conducted in the usual manner followed by the farmers of the district. Plants were thinned to one plant per hill 20 days after sowing. The external two ridges were left as border. Two of the remaining ridges were devoted for estimating plant growth and some characteristics. The following data were recorded: Plant height (cm), stem diameter (cm), leaf area (cm^2.plant)= $0.65\sum li^2$, while $\sum li^2$= summation of leaves length square.plant^{-1} (El-Sahookie and El-Dabas, 1982) and head diameter (cm). At harvest, ten guarded plants were taken randomly from the two inner ridges of each experimental plot and left for two weeks until fully air dried, then the following data were measured; number of seeds.head^{-1}, weight of thousand seed (g.), yield and oil, protein yield (ton.ha^{-1}). Oil seed content was determined using Soxhlet method (A.O.A.C., 1980). Nitrogen estimated after digesting seeds samples using Microkjeldahl method, then, protein percentage was calculated by multiplying the nitrogen percentage by the converting factor 6.25 (Agrawal *et al*., 1980). A representative soil sample (0-30 and 30-60 cm) was taken and analyzed before planting (table 1) to determinate some physical, chemical and nutritional properties used. The soil was screened through 2mm stainless steel sieve, and stored in a plastic bag at room temperature until use. Concentration of Zn was measured by atomic absorption spectrophotometer with wave length 213.9 nm. (A.P.H.A., 1998). Soil texture was determined by the hydrometer method. The pH and electrical conductivity (EC) were measured after 20 min of vigorous mixing samples at 1:2.5 (solid: deionized water) ratio. Available nitrogen, available phosphorus, available K and total $CaCo_3$ were determined according to the standard methods described by Black, 1965; Page *et al.*, 1982 and Tandon, 1999. In addition, the organic matter was determined by using Black method (Jackson, 1973). The experimental design was split-split plot in a Randomized Completely Block Design with arrangement keeping with zinc foliar application as main plots, the sub plots were assigned to genotypes, while timing of zinc application as sub-sub plots with three replications according to Steel and Torrie, (1980). Then Duncan's multiple range test (Duncan, 1955) was used to compare among means (SAS, 2001).

Table (1): The physical and chemical characters of the soil filed experiments in both seasons.

physical characters				
Seasons	2009-2010		2010-2011	
Depth (cm.)	0-30	30-60	0-30	30-60
Sand (%)	60.00	52.00	44.00	40.00
Silt (%)	23.00	29.00	35.00	31.00
Clay (%)	17.00	19.00	21.00	29.00
Texture	Sandy loom	Sandy loom	Silty sandy	Silty sandy
chemical characters				
O.M. ($mg.kg^{-1}$)	0.92	0.86	0.42	0.68
Available N (ppm)	50.25	35.98	42.56	22.97
Available P (ppm)	15.45	10.12	13.73	9.51
Available K (ppm)	178.00	162.00	121.00	112.00
Total $CaCo_3$ ($mg.kg^{-1}$)	28.50	26.80	30.20	28.10
Available Zn (ppm)	0.22	0.30	0.28	0.36
pH	8.42	7.83	8.23	7.65
E.C. ($mmhos.cm^{-1}$)	0.72	0.61	0.96	0.88

Results and discussion:

1- Effect of zinc application:

Data to a soil analysis (table1), it was found there was a deficiency in the available of zinc for both seasons (Zn>0.5 ppm) according to Lindsay, *et al*. (1978). I was also concluded that soil availability of zinc decreased when soil content of $CaCo_3$ and pH increased, as well as zinc increased with increasing clay and organic matter (Rammadan, *et al*. 1995). Results of statistical analysis showed that foliar application of zinc levels significantly affected all studied characters (tables 4 and 5), except head diameter in 2009-2010 season. With increasing zinc application from 0 to 7.5 $mg.l^{-1}$, plant height (8.20 and 10.85%), stem diameter (20.85 and 25.80%), leaf area (13.01 and 13.13%), no. of $seeds.head^{-1}$ (9.62 and 10.06%) weight of thousand seed (9.37 and 10.10%), seed yield per plant (21.85 and 20.68%), total seed yield per hectar (21.88 and 20.71%), oil yield (29.07 and 28.38%) and protein yield (34.51 and 28.94%) generally tended to increase in 2009-2010 and 2010-2011 seasons, respectively (tables 2 and 3). While increasing zinc application levels from 7.5 to 15 $mg.l^{-1}$ cause a significant decrease in all investigated characteristics in the two growing seasons. The beneficial effect of zinc could be attributed to its vital role in the activity of growth enzymes which lead to increase in the biological processes and this in turn increase plants yield components, and it has an important effect in photosynthesis process and effect on O_2 releasing during water photolysis process, carbohydrate synthesis and lipid metabolism. Also, zinc is an necessary element for the durability of chloroplast and some of proteins synthesis. These results means that zinc application up to 7.5 $mg.l^{-1}$ was great enough to increase the leaf blade area.

These findings confirmed those obtained by Hilton and Zubriski, (1985); Jahangir *et al*., (2006); Osman and Awed, (2010). Zinc increases seed and oil yields by influencing a number of growth parameters such as seeds per head and seed weight and by producing more vigorous growth and development (tables 2 and 3). These results are in harmony with those obtained by Praksh and Halaswamy, (2004); Tuncay *et al*., (2004). The superiority of 2009-2010 season in most growth characters and yield components such as plant height, stem diameter, leaf area, head diameter, no. of seeds.head^{-1}, weight of thousand seed and oil yield may be due to the high available of nutrients in experimental site of this season (table1).

2- Effect of genotypes:

Effect of genotypes on growth characters, yield and quality were contradictory (tables 4 and 5). All investigated characteristics were significantly affected by genotypes, except head diameter and weight of thousand seed in 2009-2010 season. Fodak genotype surpassed significantly Manon and Sunbred genotypes in a descending compared to the other two tested genotypes in the two seasons (tables 2 and 3). Fodak genotype gave a high mean for characters plant height (160.95 and 134.42 cm), stem diameter (2.68 and 2.19 cm), leaf area (3432.78 and 3362.16 cm^2.plant) and number of seed per head (1081.47 and 1018.20) in both seasons 2009-2010 and 2010-2011, respectively. However, the differences in most growth characteristics may be attributed to genetic factors and their interaction with the prevailing environmental conditions. Fodak genotype surpassed significantly Manon and Sunbred genotypes in seed yield per plant (73.63 and 68.56), total seed yield (3.068 and 2.856 ton.ha$^-$1), seed oil content (40.12 and 39.22%), oil yield (1.240 and 1.11973 ton.ha^{-1}), seed protein content (14.78 and 15.70%) and protein yield (0.452 and 0.463 ton.ha^{-1}) in both seasons 2009-2010 and 2010-2011, respectively (table 3). This increase in oil yield (ton.ha^{-1}) from Fodak genotype may be due to their high seed yield per hectar and seed oil content (table 3). The superiority of Fodak genotype in the most seed characters may be due to that Fodak genotype had better vegetative growth and hence photosynthetic area which led to more carbohydrates which was translocated from the source (leaves and stem) to the sink (seeds) (Mengel and Kirkby, 1982). In this concern, Awad and Griesh, (1992), Abou-Kresha *et al.,* (1996); Ibrahim *et al*., (2003) and Al-Doori and Al-Dulaimy, (2012) showed that the larger head size of Mlabar genotypes had more number of seeds per plant than the others sunflower genotypes. The superiority of Fodak genotype in the seed yield production may be attributed to having highest area of photosynthetic number of leaves per plant and this in turn increased the capacity of dry matter accumulation in the different plant parts. In this report, Kene *et al.*, (1992); Herdem, (1999); Al-Doori, (2012) and Al-Doori and Hasan, (2012) reported that Flame genotype had highest seed yield and oil yield than the Morden and Manon genotypes.

Table (2): Mean values of some growth characters and yield components as affected by zinc levels and timing application for the sunflower genotypes in 2009-2010 and 2010-2011 seasons.

Mains effect and interactions	plant height (cm)		stem diameter (cm)		leaf area ($cm^2.plant^{-1}$)		head diameter (cm)		no. of $seeds.head^{-1}$		1000 seed weight (gm)	
	2009-2010 season	2010-2011 season	2009-2010 season	2010-2011 season	2009-2010 season	2010-2011 season	2009-2010 season	2010-2011 season	2009-2010 season	2010-2011 season	2009-2010 season	2010-2011 season
Zinc levels (Zn):												
Zn_1:0 $mg.L^{-1}$	150.47c	125.08c	2.35c	1.86c	3154.69b	3091.21c	22.07	20.78c	1016.50c	953.57c	60.19b	60.55c
Zn_2:7.5 $mg.L^{-1}$	162.82a	138.66a	2.84a	2.34a	3565.31a	3497.20a	23.36	22.30a	1114.29a	1049.58a	65.83a	66.67a
Zn_3:15 $mg.L^{-1}$	156.36b	130.86b	2.59b	2.07b	3380.97a	3308.62b	22.21	21.57b	1057.18b	992.62b	62.34b	63.32b
Genotypes (G):												
G1: Manon	155.78ab	131.49b	2.58ab	2.08b	3363.12ab	3299.32b	22.56	21.55b	1061.41ab	996.36b	62.70	63.45ab
G2: Fodak	160.95a	134.42a	2.68a	2.19a	3432.78a	3362.16a	22.93	21.82a	1081.47a	1018.20a	63.95	64.70a
G3: Sunbred	152.92b	128.69c	2.52b	2.00b	3305.07b	3235.55b	22.15	21.29c	1045.10b	981.21b	61.72	62.39b
Timing application of Zn												
T1: heading stage	138.22c	108.37c	2.01c	1.44c	2867.48c	2825.63c	20.77c	19.56c	944.35c	877.75c	54.63c	55.71c
T2: flowering stage	173.32a	150.79a	3.24a	2.75a	3896.73a	3798.43a	23.92a	23.44a	1186.52a	1124.52a	72.25a	72.15a
T3: seed filling stage	158.11b	135.44b	2.53b	2.07b	3336.76b	3272.97b	22.95b	21.65b	1057.10b	993.49b	61.48b	62.67b
Interactions:												
Zn × G	N.S.	*	N.S.	*	N.S.	N.S.	N.S.	N.S.	N.S.	*	N.S.	*
Zn × T	N.S.	N.S.	*	**	N.S.	N.S.	N.S.	N.S.	*	**	N.S.	N.S.
G × T	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Zn × G × T	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

The mean values with in column followed by different letters are significantly at 0.05 and 0.001 level.
*: Significant at $p<0.05$, **: Significant at $p<0.001$, respectively. N.S. not significant.

Table (3): Mean values of yield and quality as affected by zinc levels and timing application for the sunflower genotypes in 2009-2010 and 2010-2011 seasons.

Mains effect and interactions	seed yield ($gm.plant^{-1}$)		seed yield ($ton.ha^{-1}$)		seed oil content (%)		oil yield ($ton.ha^{-1}$)		seed protein content (%)		protein yield ($ton.ha^{-1}$)	
	2009-2010 season	2010-2011 season	2009-2010 season	2010-2011 season	2009-2010 season	2010-2011 season	2009-2010 season	2010-2011 season	2009-2010 season	2010-2011 season	2009-2010 season	2010-2011 season
Zinc levels (Zn):												
Zn_1:0 $mg.L^{-1}$	64.37c	60.04c	2.682c	2.501c	38.63c	37.74c	1.042c	0.937c	13.80c	15.01c	0.368c	0.387c
Zn_2:7.5 $mg.L^{-1}$	78.44a	72.46a	3.269a	3.019a	40.93a	39.87a	1.345a	1.203a	15.24a	16.04a	0.495a	0.499a
Zn_3:15 $mg.L^{-1}$	70.57b	65.98b	2.941b	2.749b	39.68b	38.80b	1.171b	1.060b	14.48b	15.49b	0.421b	0.438b
Genotypes (G):												
G1: Manon	70.76b	65.81b	2.949b	2.742b	39.84a	38.85b	1.182b	1.061b	14.53b	15.51b	0.426b	0.438b
G2: Fodak	73.63a	68.56a	3.068a	2.856a	40.12a	39.22a	1.240a	1.119a	14.78a	15.70a	0.452a	0.463a
G3: Sunbred	68.99b	64.12c	2.875b	2.671c	39.28b	38.34b	1.136c	1.020c	14.22c	15.33b	0.407c	0.423b
Timing application of Zn												
T1: heading stage	56.33c	52.48c	2.347c	2.186c	36.94c	36.15c	0.864c	0.774c	12.86c	14.22c	0.297c	0.317c
T2: flowering stage	87.18a	81.79a	3.633a	3.408a	42.53a	41.59a	1.543a	1.407a	16.21a	16.91a	0.579a	0.587a
T3: seed filling stage	69.87b	64.21b	2.911b	2.675b	39.76b	38.67b	1.151b	1.019b	14.44b	15.41b	0.409b	0.419b
Interactions:												
Zn × G	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Zn × T	**	**	**	**	N.S.	*	**	**	**	**	**	**
G × T	N.S.	*	N.S.	*	N.S.	N.S.	N.S.	*	N.S.	N.S.	**	N.S.
Zn × G × T	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

The mean values with in column followed by different letters are significantly at 0.05 and 0.001 level.
*: Significant at p<0.05, **: Significant at p<0.001, respectively. N.S. not significant.

3- Effect timing of zinc foliar application:

Data reported in tables (2 and 3) indicate a significant effect of timing application on all sunflower attributes. The promising stage of Zn application was flowering stage for sunflower attributes criteria, these results are true in the two growing seasons. When zinc application was delaying from heading stage to flowering stage, plant height, stem diameter, leaf area, head diameter, no. of seeds.head^{-1}, weight of thousand seed, seed yield per plant, total seed yield per hectar, oil yield and protein yield were increased approximately 25.39, 61.19, 35.89, 15.16, 25.64, 32.25, 54.76, 54.79, 78.58, 81.78 and 94.94 % in 2009-2010 season and 39.14, 90.97, 34.42, 19.83, 28.11, 29.50, 55.84, 55.90, 81.78 and 85.17% in 2010-2011 season, respectively. higher yield components and oil content by delaying Zn application to the leaves plant at flowering stage may be due to best stage for Zn application which is led to growth and development of the crop, that resulted in photosynthetic products accumulated in the source (leaves) and transported to the sink (seeds) (tables 2 and 3), which enhanced the oil content. The same results were obtained by Mengel *et al.*, (2001); Kathirresan *et al.*, (2001); Martin, *et al*., (2007) and Babaeian *et al*., (2011), who found that the zinc foliar application at flowering stage produced taller plants.

4- Interactions effect:

The interaction between zinc application and genotypes showed significant effects on plant height, stem diameter, no. of seeds.head^{-1} and 1000 seed weight in 2010-2011 season only, as illustrated in tables (4 and 5). The interaction between zinc foliar application and genotypes for the other investigated traits were not statistically significant in both seasons, therefore the data were excluded. It was evident from tables (4 and 5), that seed oil content as affected by interaction between zinc foliar application and timing application in 2010-2011 season only, stem diameter, no. of seeds.head^{-1}, seed yield per plant, total seed yield per hectar, oil yield, seed protein content and protein yield in both seasons. The insignificant effect between zinc foliar application and timing application on other characteristic showed that each of these two factors acted independently on these traits. The interaction between the genotypes with timing of zinc foliar application was significant in protein yield in 2009-2010 season only, seed yield per plant, total seed yield per hectar and oil yield in 2010-2011 season as illustrated in tables (4 and 5). The interaction among the three studying factors (zinc foliar application, genotypes and timing of zinc application) for the other investigated traits were not statistically significant in both seasons, therefore the data were excluded (tables 4 and 5).

Table (4): Analysis of variance F values for some growth characters and yield components in 2009-2010 and 2010-2011 seasons.

S.O.V	D.f	M.S. for 2009 - 2010 season					
		plant height (cm)	stem diameter (cm)	leaf area ($cm^2.plant^{-1}$)	head diameter (cm)	no. of $seeds.head^{-1}$	1000 seed weight (gm)
Replications	2	21196.20496	22.43929259	1141870.88	52.4772198	210332.0157	778.230283
A	2	1030.52455**	1.63051481**	1142089.87*	13.5318679 N.S.	65169.2832**	218.962712*
$Error_a$	4	49.85096	0.03262407	69256.81	3.8104309	1902.7754	12.177694
B	2	447.08544**	0.17029259**	110394.65**	4.0364679 N.S.	8960.7742**	33.666038 N.S.
A × B	4	8.54154 N.S.	0.00910741 N.S.	3456.38 N.S.	0.0977568 N.S.	208.3876 N.S.	2.744910 N.S.
$Error_b$	12	25.85278	0.00874136	4372.14	0.1357994	253.7762	1.287948
C	2	8367.09141**	10.24680000**	7169244.72**	70.3212235**	396489.3516**	2131.655053**
A × C	4	57.57500 N.S.	0.12670370*	57647.61 N.S.	5.8556957 N.S.	5403.2922*	5.882420 N.S.
B × C	4	15.87006 N.S.	0.03995926 N.S.	3408.51 N.S.	0.2431235 N.S.	837.8325 N.S.	0.761740 N.S.
A×B × C	8	5.91319 N.S.	0.01364907 N.S.	8502.07 N.S.	0.2058373 N.S.	883.4595 N.S.	1.825896 N.S.
$Error_c$	36	129.27845	0.04146173	38674.06	2.7458420	1945.3653	15.863762
Total	81						
S.O.V	D.f	M.S. for 2010 - 2011 season					
Replications	2	5089.96715	3.53470586	3161133.58	152.3490605	716708.727	1337.864683
A	2	1254.13907**	1.59920586**	1114438.51**	15.4987605**	62940.215**	254.022138**
$Error_a$	4	26.47533	0.01605772	26426.07	0.3223272	816.313	1.640507
B	2	221.27625**	0.22846327**	108204.37**	1.9306892**	9333.255**	36.181430**
A × B	4	24.78217*	0.01476790*	292.00 N.S.	0.0034614 N.S.	691.889*	1.824103*
$Error_b$	12	5.59750	0.00341728	1117.83	0.0137235	165.443	0.537096
C	2	12455.84899**	11.55309660**	6401571.56**	101.6814531**	411583.955**	1838.751083**
A × C	4	72.08988 N.S.	0.20056790**	52572.83 N.S.	0.2534517 N.S.	5514.002**	6.065354 N.S.
B × C	4	22.79041 N.S.	0.02401975 N.S.	3943.25 N.S.	0.1057985 N.S.	677.570 N.S.	0.644504 N.S.
A×B × C	8	8.86076 N.S.	0.01883827 N.S.	8218.70 N.S.	0.0583380 N.S.	691.984 N.S.	2.841425 N.S.
$Error_c$	36	65.95480	0.03006667	26048.65	0.1437552	1470.478	8.586695
Total	81						

*: Significant at $p<0.05$, **: Significant at $p<0.001$, respectively. N.S. not significant.

Table (5): Analysis of variance F values for yield and quality in 2009-2010 and 2010-2011 seasons.

S.O.V	D.f	seed yield ($gm.plant^{-1}$)	seed yield ($ton.ha^{-1}$)	seed oil content (%)	oil yield ($ton.ha^{-1}$)	seed protein content (%)	protein yield ($ton.ha^{-1}$)
		M.S. for 2009 - 2010 season					
Replications	2	4438.97671	7.70655679	109.0145642	0.71587799	234.7687444	0.00008074
A	2	1342.69084**	2.33106049**	35.9027494**	0.62556200**	14.0010815**	0.10986486**
$Error_a$	4	50.83698	0.08825864	0.2029864	0.01554432	0.2687481	0.00044093
B	2	148.05831**	0.25704568**	4.9636679**	0.07353870**	2.0994778**	0.01410840**
A × B	4	1.32978 N.S.	0.00230864 N.S.	0.2076235 N.S.	0.00216207 N.S.	0.0765926 N.S.	0.00058974 N.S.
$Error_b$	12	4.41529	0.00766543	0.1262364	0.00142863	0.0471710	0.00020381
C	2	6453.77351**	11.20446790**	210.5939272**	3.13895722**	75.8192259**	0.54657959**
A × C	4	104.71538**	0.18179753**	0.8844605 N.S.	0.05071686**	1.2198741**	0.01316435**
B × C	4	19.13244 N.S.	0.03321605 N.S.	0.1052901 N.S.	0.00835665 N.S.	0.2699204 N.S.	0.00259754**
A×B × C	8	3.87431 N.S.	0.00672623 N.S.	0.4423651 N.S.	0.00300827 N.S.	0.1589713 N.S.	0.00069388 N.S.
$Error_c$	36	12.69333	0.02203704	0.4991228	0.00436362	0.1506000	0.00025195
Total	81						
S.O.V	D.f	M.S. for 2010 - 2011 season					
Replications	2	9784.94560	16.98775278	276.3072402	1.31989443	106.5727527	0.84727553
A	2	1041.49813**	1.80815648**	30.5070744**	0.47857547**	7.1953676**	0.08576051**
$Error_a$	4	13.46453	0.02337593	0.4167290	0.00523308	0.1841157	0.00212960
B	2	135.56320**	0.23535278**	5.3399410**	0.06658837**	0.9095120**	0.01113201**
A × B	4	2.10053 N.S.	0.00364676 N.S.	0.1577244 N.S.	0.00166264 N.S.	0.0195560 N.S.	0.00034916 N.S.
$Error_b$	12	1.87716	0.00325895	0.0970160	0.00064021	0.0171080	0.00023977
C	2	5877.69973**	10.20433981**	200.6865318**	2.75163118**	49.1500333**	0.50264392**
A × C	4	106.74667**	0.18532407**	1.7863998*	0.06036515**	0.4690426**	0.01056874**
B × C	4	26.58293*	0.04615093*	0.1942012 N.S.	0.01230274*	0.0800523 N.S.	0.00227278 N.S.
A×B × C	8	3.81387 N.S.	0.00662130 N.S.	0.2718012 N.S.	0.00224532 N.S.	0.0429921 N.S.	0.00037997 N.S.
$Error_c$	36	7.69280	0.01335556	0.4759627	0.00316683	0.1055213	0.00149473
Total	81						

*: Significant at $p<0.05$, **: Significant at $p<0.001$, respectively. N.S. not significant.

5- Correlations:

The correlation was high significant positive among leaf area, head diameter, no. of seeds.head^{-1}, weight of thousand seed with seed yield per plant and total seed yield per hectar, while the correlation was negative and significant between protein percentage with seed yield per plant and total seed yield per hectar in 2009-2010 and 2010-2011 seasons as illustrated in table (6).

6- Conclusions:

Despite the differences among genotypes of sunflower crop, the flowering stage of zinc foliar application was the most limiting factor for seed yield and oil yield in this study for both seasons.

Table (6): Simple correlation coefficient among some growth characters and yield components for the sunflower genotypes in 2009-2010 and 2010-2011 seasons.

	plant height (cm)	stem diameter (cm)	leaf area ($cm^2.plant^{-1}$)	head diameter (cm)	no. of seeds.head^{-1}	1000 seed weight (gm)	seed yield ($gm.plant^{-1}$)	seed yield ($ton.ha^{-1}$)	seed oil content (%)	oil yield ($ton.ha^{-1}$)	seed protein content (%)	protein yield ($ton.ha^{-1}$)
2009-2010 season												
plant height (cm)	1.00000	0.25835*	0.71031**	0.69819**	0.40980**	0.29578**	0.05589$^{N.S.}$	0.0558$^{N.S.}$	0.79227**	0.24540*	0.78755**	0.52254**
stem diameter (cm)		1.00000	0.35342**	0.59119**	0.0532$^{N.S.}$	0.1598$^{N.S.}$	0.20322*	0.2032$^{N.S.}$	0.74195**	0.361$^{N.S.}$	0.71080**	0.58089**
leaf area ($cm^2.plant^{-1}$)			1.00000	0.68680**	0.87082**	0.83728**	0.70309**	0.70309**	0.79357**	0.82275**	0.50017**	0.88444**
head diameter (cm)				1.00000	0.36439**	0.39971**	0.22461*	0.22461*	0.82469**	0.39653**	0.72732**	0.59045**
no. of seeds.head^{-1}					1.00000	0.94093**	0.87707**	0.87707**	0.47560**	0.90336**	0.08564$^{N.S.}$	0.79787**
1000 seed weight (gm)						1.00000	0.91779**	0.91779**	0.46973**	0.93228**	0.05803$^{N.S.}$	0.79840**
seed yield ($gm.plant^{-1}$)							1.00000	1.00000**	0.33959**	0.97152**	-0.07660$^{N.S.}$	0.79101**
seed yield ($ton.ha^{-1}$)								1.00000	0.33959**	0.97152**	-0.07660$^{N.S.}$	0.79101**
seed oil content (%)									1.00000	0.54649**	0.88505**	0.80718**
oil yield ($ton.ha^{-1}$)										1.00000	0.15034$^{N.S.}$	0.90631**
seed protein content(%)											1.00000	0.53879**
protein yield ($ton.ha^{-1}$)												1.00000
2010-2011 season												
plant height (cm)	1.00000	0.79551**	0.44480**	0.1881$^{N.S.}$	0.1574$^{N.S.}$	0.33381**	0.1395$^{N.S.}$	0.1395$^{N.S.}$	0.92251**	0.41026**	0.18153$^{N.S.}$	0.1529$^{N.S.}$
stem diameter (cm)		1.00000	0.50355**	0.31329**	0.32114**	0.45658**	0.38001**	0.38001**	0.78697**	0.62622**	0.15867$^{N.S.}$	0.30306**
leaf area ($cm^2.plant^{-1}$)			1.00000	0.94359**	0.93181**	0.97154**	0.90992**	0.90992**	0.2049 N.S.	0.94316**	0.88619**	0.94118**
head diameter (cm)				1.00000	0.98006**	0.96183**	0.96435**	0.96435**	-0.083$^{N.S.}$	0.90503**	0.90754**	0.98107**
no. of seeds.head^{-1}					1.00000	0.95628**	0.98070**	0.98070**	-0.103$^{N.S.}$	0.92290**	0.86333**	0.98942**
1000 seed weight (gm)						1.00000	0.94267**	0.94267**	0.0923 N.S.	0.94127**	0.87400**	0.96065**
seed yield ($gm.plant^{-1}$)							1.00000	1.00000**	-0.088$^{N.S.}$	0.94978**	0.80821**	0.97592**
seed yield ($ton.ha^{-1}$)								1.00000	-0.088$^{N.S.}$	0.94978**	0.80821**	0.97592**
seed oil content (%)									1.00000	0.22200**	-0.07161**	-0.093$^{N.S.}$
oil yield ($ton.ha^{-1}$)										1.00000	0.74913**	0.92042**
seed protein content(%)											1.00000	0.90495**
protein yield ($ton.ha^{-1}$)												1.00000

*: Significant at $p<0.05$, **: Significant at $p<0.001$, respectively. N.S. not significant.

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